TM-744
1600.000

MEASUREMENTS OF HEAT CONDUCTION BETWEEN 300K AND 80K

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INTRODUCTION

In order to evaluate the thermal performance of several support members for the Energy Doubler cryostat, a special device was designed and used. Here we present a description of a "heat flow meter" and the result of measurements on several proposed supports. Renewed interest in this problem was caused by the need to use stronger supports than the E22-14 type rollers. These measurements together with the known total heat load on the LN_2 shield direct our attention towards where possible reductions in this load can be made.

APPARATUS

Thermal conductance measurements of insulators usually involve solid pieces provided with thermometers and heaters. In analogy with electrical electrodes these pieces could very properly be called "thodes". In our apparatus the insulator under test is compressed between two thodes; one kept at 300K and the second near liquid N_2 temperature. The environment is vacuum with the container walls at liquid N_2 temperature. In these kind of measurements thermal contact and infrared radiation are usually pitfall sources. Here they are taken care of by: 1) varying the compressional force; a parameter that yields information on thermal contact resistance, and 2) the calibration procedure used which compensates for the infrared radiation component.

A thermistor in the 300K thode is used by an electronic controller to stabilize its temperature. (Another thermistor in the same thode serves as a thermometer.)

The low temperature thode has a radiation guarded body of stainless steel consisting of a cylinder between two sensitive copper wire "thermometers". A calibration heater is wound close to the sample contacting surface. A copper bar on the other side of the body connects it to a liquid N_2 temperature sink (see Fig. 1). The heat path is such as to force the heat coming from the sample or from the calibration heater to go through the radiation guarded body. A carbon thermometer installed in the cylinder serves as an extra temperature monitor.

When adapters are needed between the sample and the thodes, indium foils and GE7031 are used to improve thermal contact and to hold the parts in place.

MEASUREMENT

A typical set of measurements is made by first calibrating the cold thode with the sample installed on it but not touching the upper thode which is maintained at 300K. Under this condition a calibration curve like Fig. 2 is obtained where the vertical scale is the difference in the resistance of the two copper thermometers.

Four lead techniques are used to measure both the resistances and the power dissipated in the calibration heater. Current reversal is used to eliminate thermal emf effects.

The top thode is then brought down to compress the sample, each data point requires ≃20 minutes for achieving thermal equilibrium. The sequence of points is recorded so that recognition of mechanical deformation can be made.

Figures 3 to 7 presents the data, most of which was collected at a rate of one sample/day. From samples with simple geometry, the thermalconductivity integral from 85K to 300K of the material can be extracted. Table I presents these results.

CONCLUSIONS RELATIVE TO E22-14 CRYOSTATS

Independent measurements[1] established an average shield load of 34W at an average shield temperature of 47.7K and mechanical load of 520.lb. According to Carnot's Law for the shield at 78K the load will be 20.8W in reasonable agreement with later measurements[2]. Extrapolating the results obtained with the rollers (Fig. 3) for the interval 300K to 78K we conclude that the 35 rollers of these cryostats contributed with 6.87W and therefore 13.9W have to be explained as infrared and junction box contributions.

Substitution of rollers by trapezoids (Fig. 4) will increase the heat load by $35 \times (.29-.19)(\frac{300-78}{300-85}) = 3.6$ watts or 17%. Rough estimates of the infrared radiation leads us to believe that it should be a few watts (2 or 4). Therefore, compensation for this increase, required by needed support strength, seems to be possible by improvements in; 1) multilayer insulation, and 2) details of the junction box.

CONCLUSIONS RELATIVE TO MEASURED THERMAL CONDUCTIVITY INTEGRALS

From Table I we conclude that thermal conductivity integral between 85K and 300K of G-10, perpendicular to the fabric, is higher than the Dacron tube used. However, when mechanical properties are taken into account G-10 presents a better elastic constant heat flow merit figure.

ACKNOWLEDGEMENT

On most of the samples, all phases of data taking were expertly carried out by J. Tague.

REFERENCES

1. M.Kuchnir, E22-14 Cryostat Boil-Off, Fermilab TM-740, July 1977.
2. C.H.Rode memo on B-12 test, August 30, 1977.
3. G.Biallas, R.J.Stanczak's compression measurements of September 2, 1977, (informal communication).

TABLE I

HEAT CONDUCTION DATA SUMMARY

SAMPLE	HEAT FLOW*	CROSS SECTION AREA/LENGTH RATIO	$\int_{85K}^{300K} \kappa\, dT$	MERIT FIGURE**
G-10 Roller	.215W	-	-	-
G-10 Trapezoid	.302	-	-	411.
G-10 Rod	.835	1.041 cm	.802 W/cm	-
Dacron Tube	.721	1.348	.535	143.
Epoxi Filled Tube	.266	.757	.351	338.

* Under conditions of minimum contact resistance (usually under 900 lbs. of compressive force).

**This figure of merit is obtained by dividing the appropriately scaled spring constant measured in Ref. 3 by the heat flow.

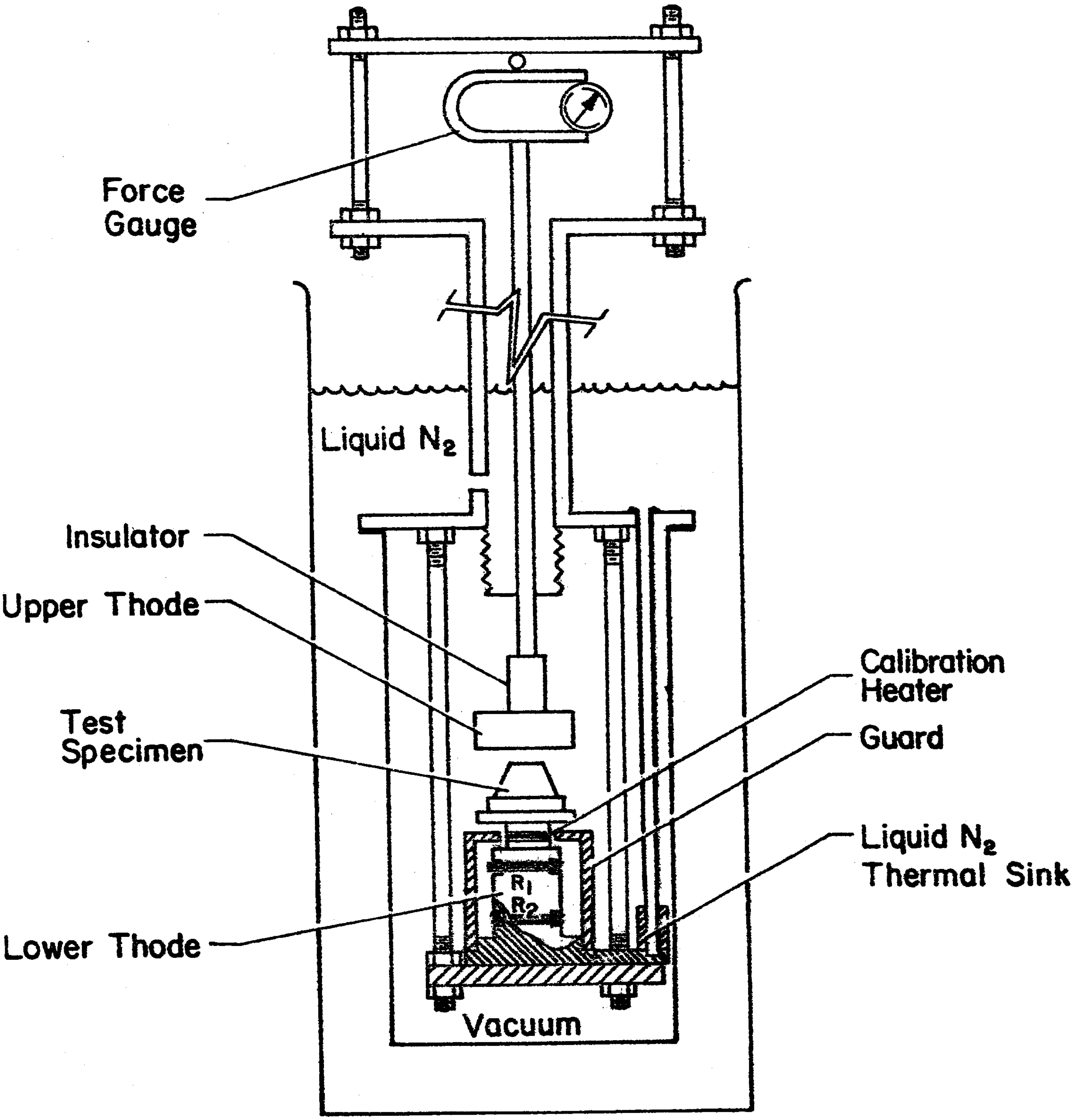


Figure 1 Apparatus for measurement of heat conduction in support samples between room temperature and liquid nitrogen temperature

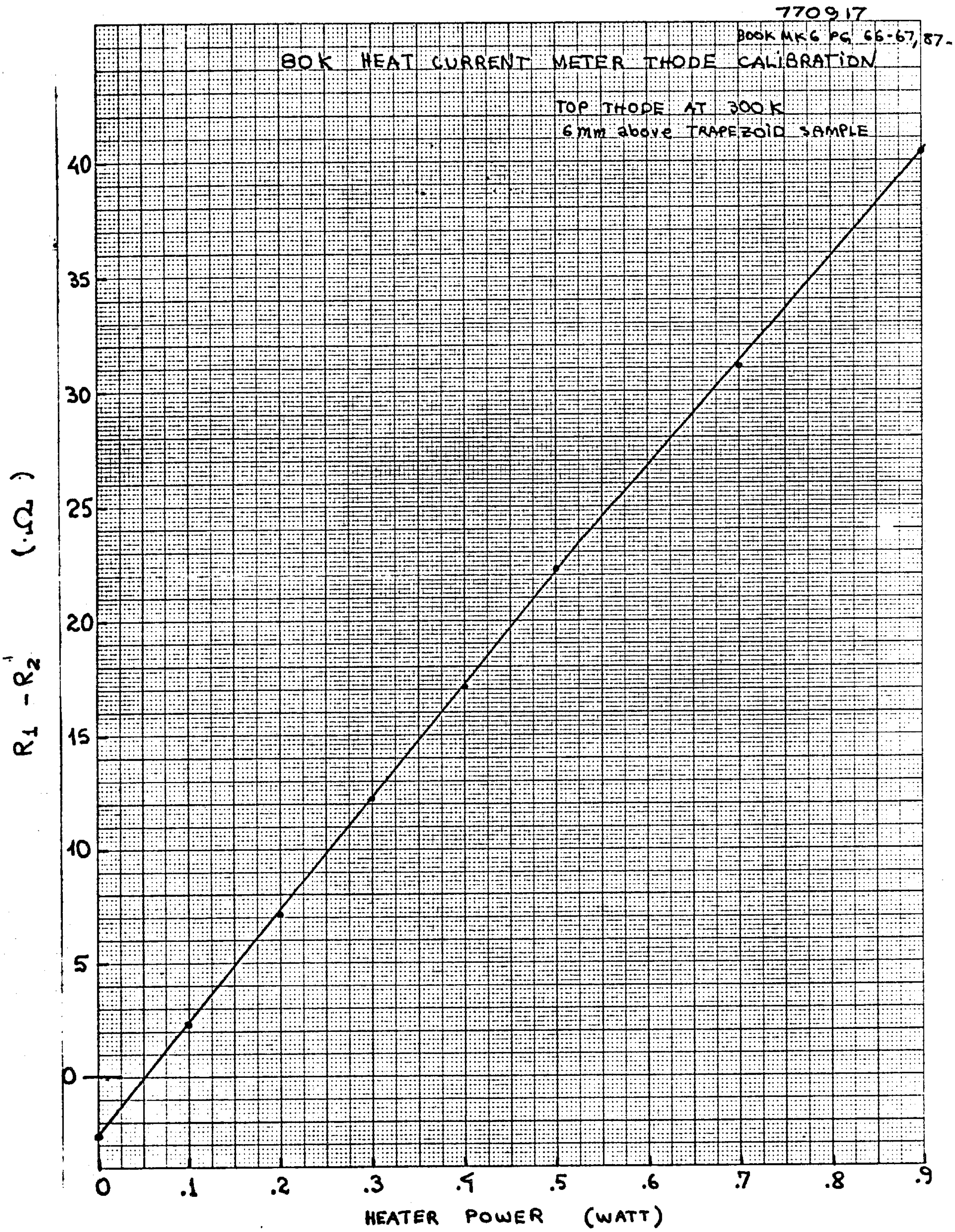


Figure 2 80K heat current meter thode calibration

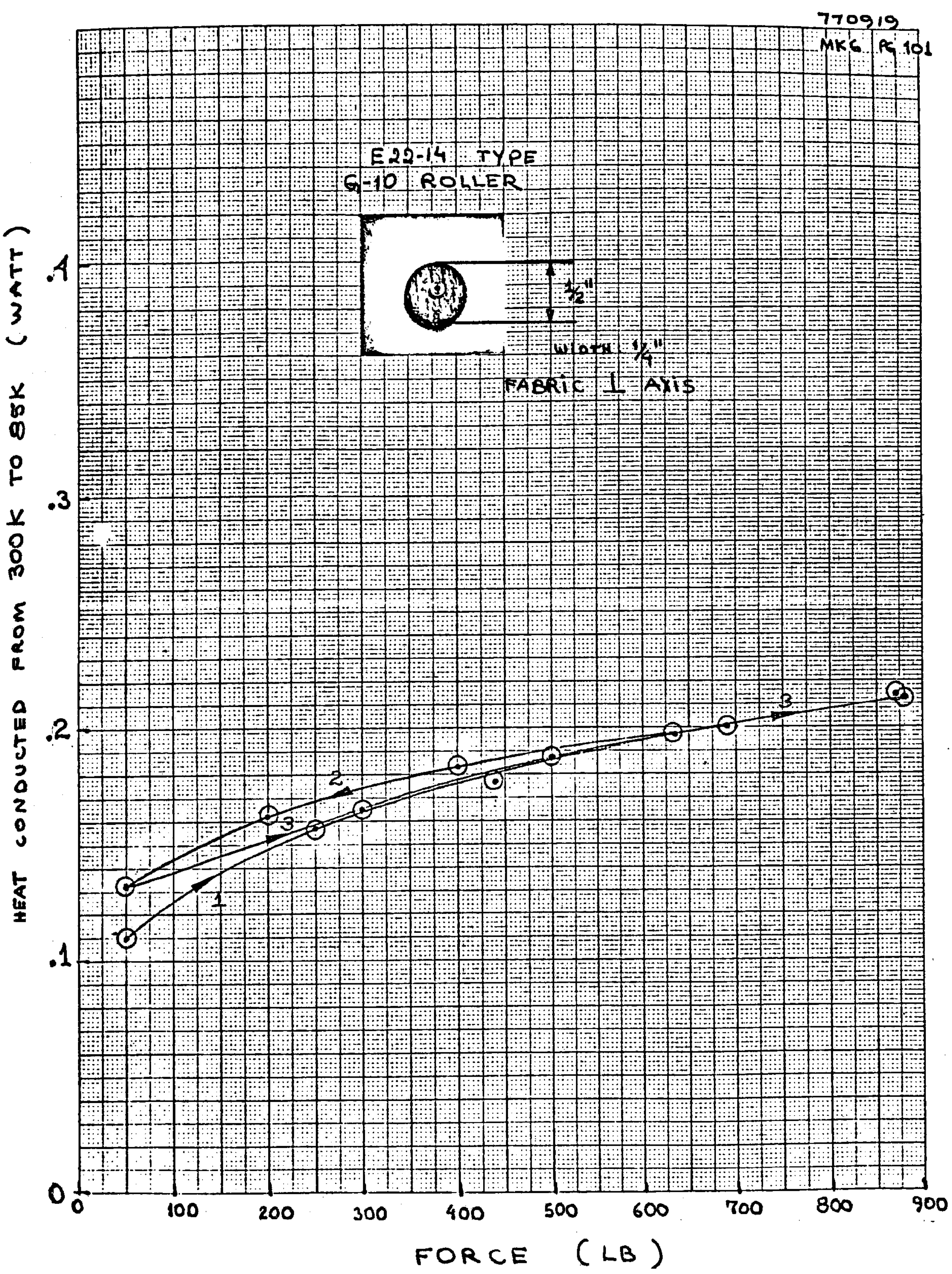

770919
MKG PG 101
E22-14 TYPE
G-10 ROLLER
1/2"
WIDTH 1/4"
FABRIC ⊥ AXIS
HEAT CONDUCTED FROM 300K TO 88K (WATT)
0
.1
.2
.3
.4
0
100
200
300
400
500
600
700
800
900
FORCE (LB)
1
2
3
3

Figure 3

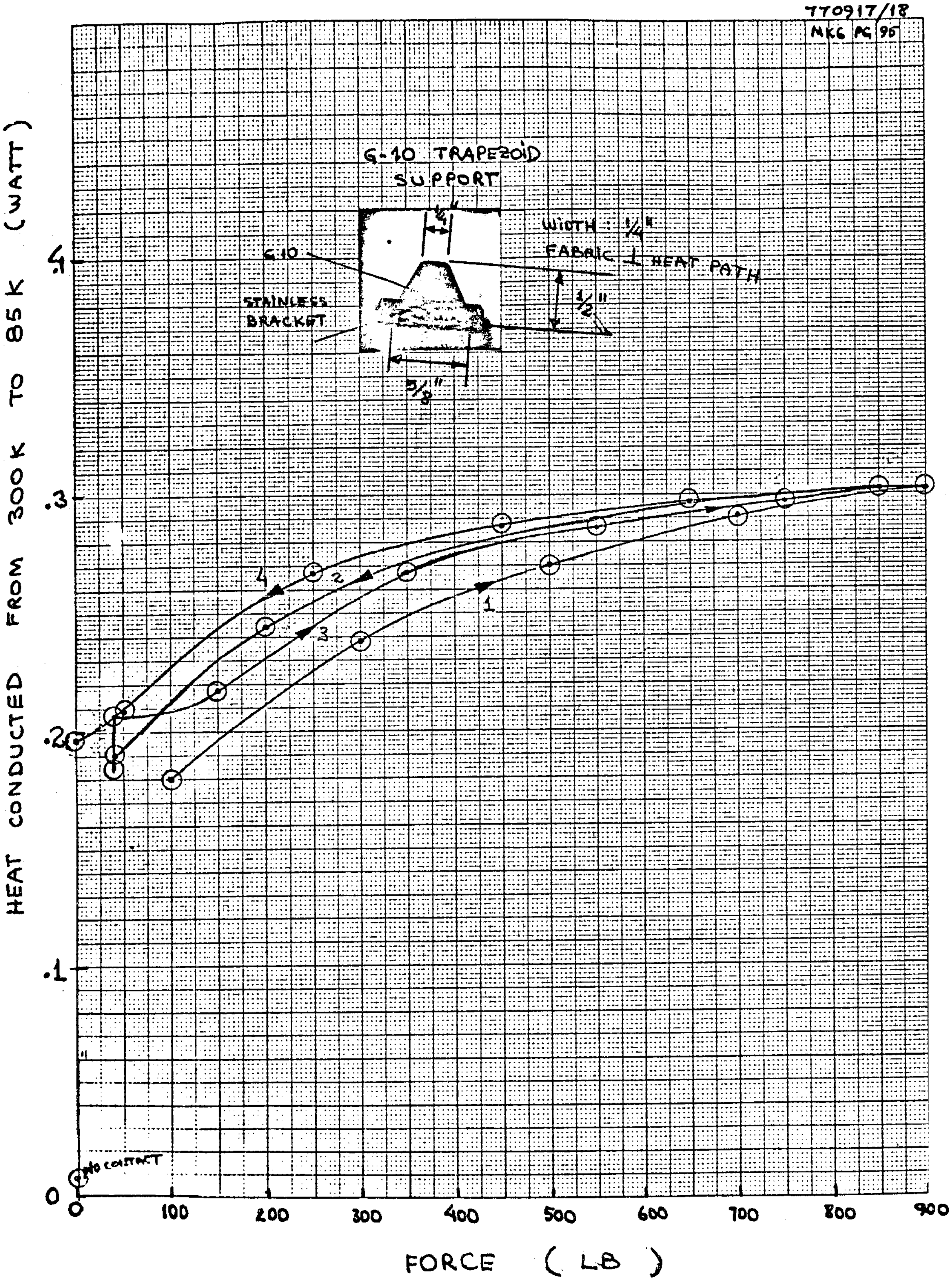

770917/18
MKG PG 95
G-10 TRAPEZOID SUPPORT
1/4"
WIDTH : 1/4"
FABRIC ⊥ HEAT PATH
G10
STAINLESS BRACKET
1/2"
5/8"
HEAT CONDUCTED FROM 300K TO 85K (WATT)
.4
.3
.2
.1
0
1
2
3
4
NO CONTACT
0
100
200
300
400
500
600
700
800
900
FORCE (LB)

Figure 4

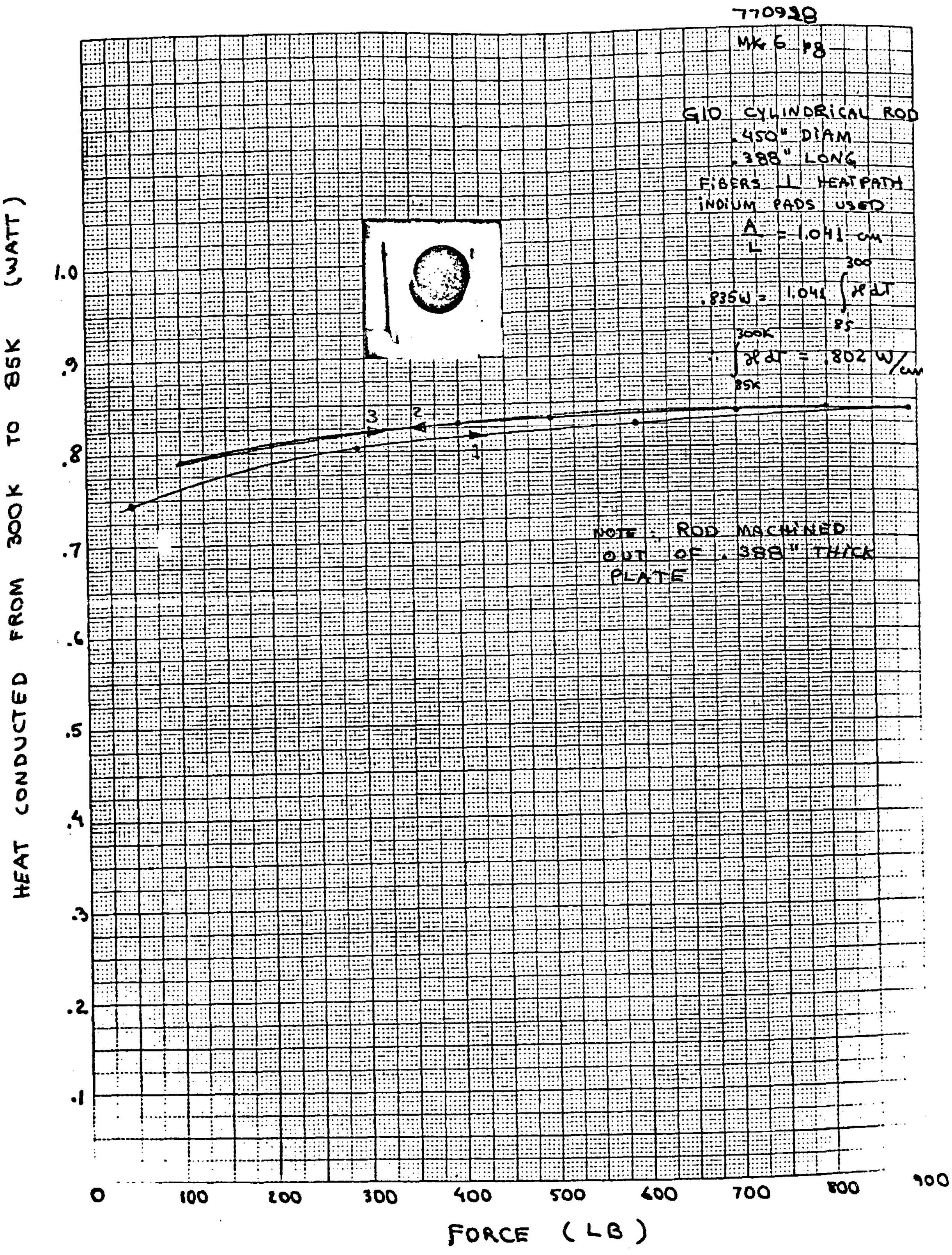
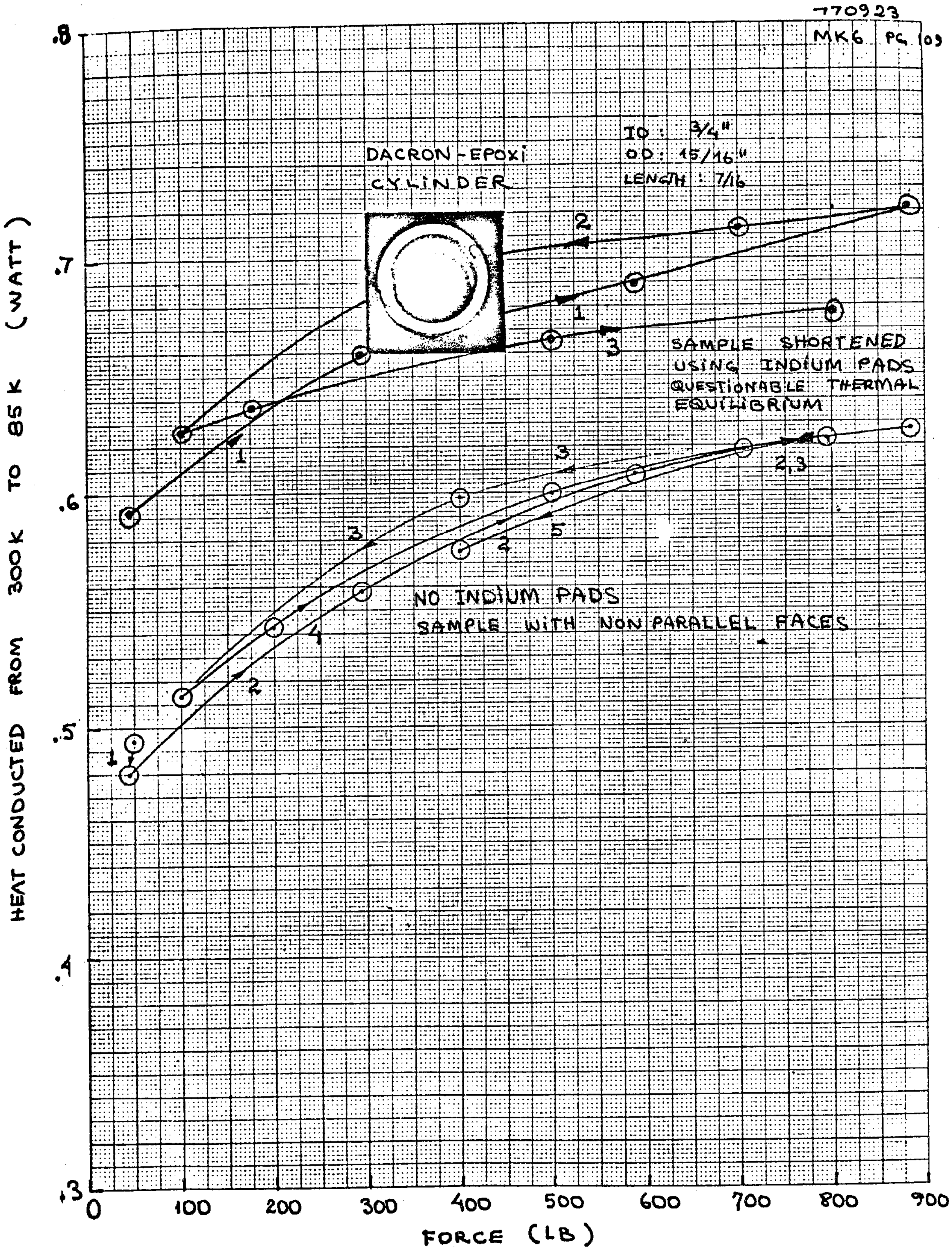

770928
MK 6 P8
G10 CYLINDRICAL ROD
.450" DIAM
.388" LONG
FIBERS ⊥ HEATPATH
INDIUM PADS USED
A/L = 1.041 cm
.835W = 1.041 ∫ 85 to 300 K dT
∫ 85K to 300K K dT = .802 W/cm
NOTE: ROD MACHINED OUT OF .388" THICK PLATE
HEAT CONDUCTED FROM 300K TO 85K (WATT)
FORCE (LB)
1
2
3
0
100
200
300
400
500
600
700
800
900
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

Figure 5



770923
MKG PG 109
DACRON-EPOXI CYLINDER
ID: 3/4"
OD: 15/16"
LENGTH: 7/16
SAMPLE SHORTENED
USING INDIUM PADS
QUESTIONABLE THERMAL EQUILIBRIUM
NO INDIUM PADS
SAMPLE WITH NON PARALLEL FACES
HEAT CONDUCTED FROM 300K TO 85K (WATT)
FORCE (LB)
.3
.4
.5
.6
.7
.8
0
100
200
300
400
500
600
700
800
900

Figure 6

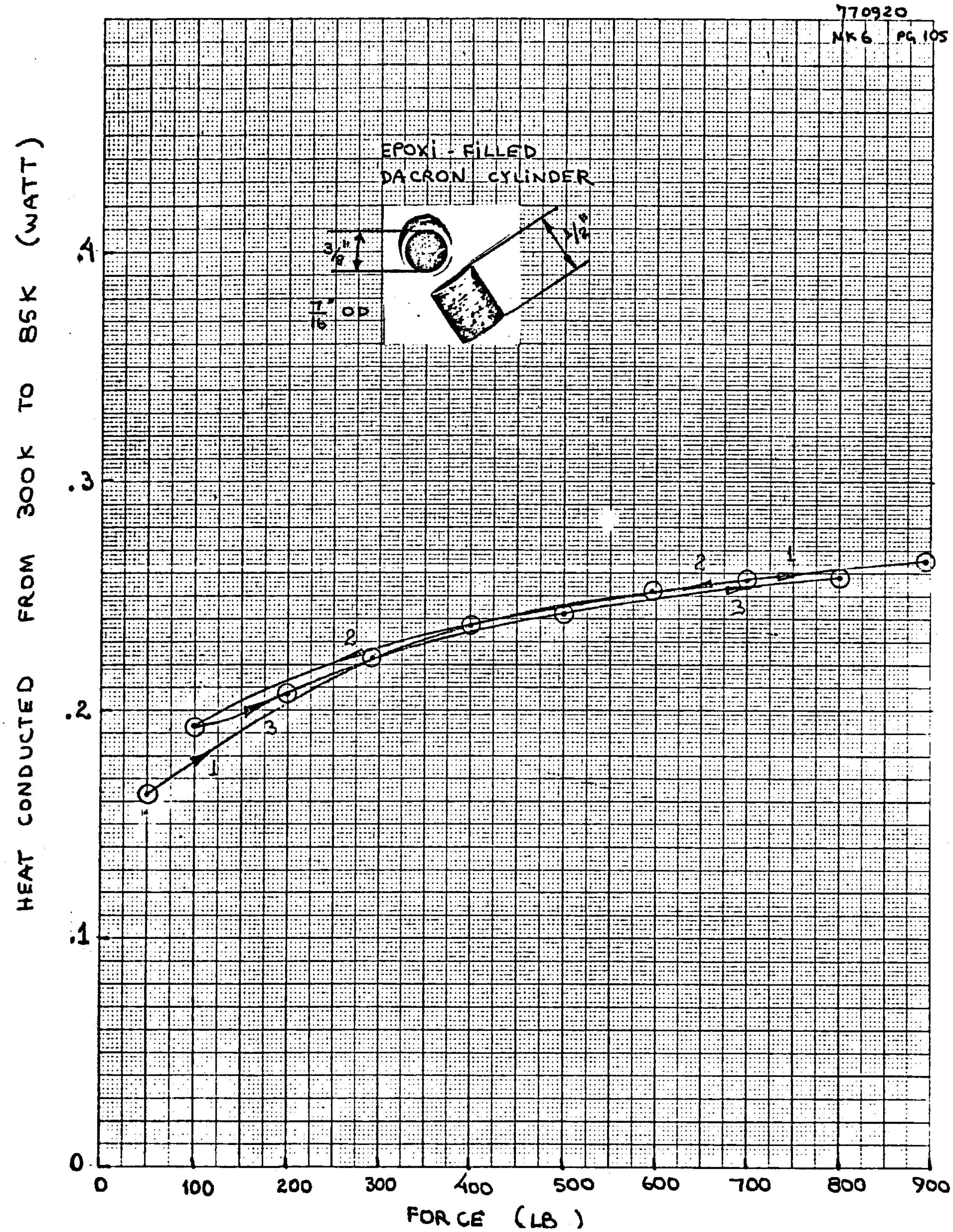

770920
NK6 PG 105
EPOXi - FILLED
DACRON CYLINDER
3/8"
7/16" OD
1/2"
HEAT CONDUCTED FROM 300K TO 85K (WATT)
.4
.3
.2
.1
0
0
100
200
300
400
500
600
700
800
900
FORCE (LB)
1
2
3

Figure 7